2. RAW MATERIALS ACQUISITION AND MANUFACTURING

The GHG emissions associated with raw materials acquisition and manufacturing are a key element of a life-cycle GHG analysis. This chapter describes how we estimated these emissions for 15 materials: aluminum cans, steel cans, glass, three types of plastic (HDPE, LDPE, and PET), corrugated cardboard, magazines/third-class mail, newspaper, office paper, phonebooks, textbooks, dimensional lumber, medium-density fiberboard, and mixed paper.

In manufacturing, substantial amounts of energy are used both in the acquisition of raw materials and in the manufacturing process itself. In general, the majority of energy used for these activities is derived from fossil fuels. Combustion of fossil fuels results in emissions of CO_2, a GHG. In addition, manufacturing of some materials also results in GHG emissions that are not associated with energy consumption. Section 2.1 addresses energy-related CO_2 emissions, and Section 2.2 covers non-energy GHG emissions. Sections 2.3 and 2.4 discuss results and limitations of the analysis, respectively.

2.1 GHG EMISSIONS FROM ENERGY USE IN RAW MATERIALS ACQUISITION AND MANUFACTURING

To begin our analysis, we estimated the GHG emissions from fossil fuel combustion for both (1) raw materials acquisition and manufacturing (referred to here as "process energy"), and (2) transportation (referred to as "transportation energy").

In this analysis, process energy GHG emissions consist primarily of CO_2.[1] The majority of CO_2 emissions are from combustion of fuels used directly, e.g., to operate mining equipment or fuel a blast furnace. CO_2 emissions from fuels used to generate electricity during the manufacturing stage also are included in process energy emissions. In addition, process energy GHG emissions include indirect emissions from "pre-combustion" activities, such as oil exploration and extraction, coal mining and beneficiation, and natural gas production.

Transportation energy GHG emissions consist of CO_2 emissions from combustion of fuels used to transport raw materials and intermediate products to the final manufacturing or fabrication facility. For transportation of recycled inputs, this analysis considers transportation (1) from the curbside to the materials recovery facility (MRF), (2) from the MRF to a broker, and (3) from a broker to the plant or mill where the recycled inputs are used. The transportation values for recycled inputs generally include the energy used to process the inputs at an MRF. Transportation of finished manufactured goods to consumers is not included in the analysis. We did not estimate transportation emissions of CH_4 or N_2O; these emissions are considerably less significant than CO_2 emissions.[2] This omission would tend to understate the GHG impacts from transportation slightly.

Emissions from raw materials acquisition and manufacturing also include CH_4 associated with producing, processing, and transporting coal, oil, and natural gas. CH_4 is emitted during the various stages of fossil fuel production because CH_4 is trapped within coal and oil deposits, and is released when they are mined. Natural gas, of course, consists largely of CH_4.

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[1] Note, however, that CO_2 emissions from combustion of biomass (e.g., in paper manufacturing) are not counted as GHG emissions (as described in Chapter 1).

[2] The *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1999* estimates 1999 emissions from transportation to be 468.1 MMTCE for CO_2 and 18.5 MMTCE for CH_4 and N_2O combined.

We developed separate estimates for GHG emissions from process and transportation energy for virgin inputs and recycled inputs, generating a total of four separate GHG emissions estimates for each material: (1) process energy with virgin inputs, (2) process energy with recycled inputs, (3) transportation energy with virgin inputs, and (4) transportation energy with recycled inputs.

2.1.1 Methodology

We developed GHG emission estimates for each material based on two sets of data: (1) the amount of each type of fuel used to make 1 ton of the material, and (2) the "carbon coefficient" for each fuel (a factor that translates the energy value of fuel combusted into the mass of GHGs emitted).

Our methodology in using these two sets of data to estimate process and transportation energy GHG emissions is best illustrated by an example: To estimate process energy GHG emissions from the production of 1 ton of newspaper from virgin inputs, we multiplied the amount of each type of fuel consumed (as measured in million Btu) by the carbon coefficient for that type of fuel (as measured in metric tons of carbon equivalent, or MTCE, per million Btu). The result was an estimate of the GHG emissions (in MTCE) from the combustion of each type of fuel required to make 1 ton of newspaper. Total process energy GHG emissions from making 1 ton of newspaper are simply the sum of the GHG emissions across all of the fuel types. To estimate the GHG emissions when electricity is used, we used the national average mix of fuels used to generate electricity.

We estimated GHGs from the energy used to transport raw materials for making 1 ton of a given product (e.g., newspaper) in the same way. The amount of each fuel used was multiplied by its carbon coefficient, and the resulting values for each of the fuels were summed to yield total transportation energy GHG emissions.

In this way, GHG estimates for raw materials acquisition and manufacturing were developed for each of the manufactured materials considered. As noted in Chapter 1, much of the energy information in this edition of the report is drawn from an effort conducted by EPA's Office of Research and Development (ORD) to construct a Decision Support Tool for solid waste managers. The remaining energy data was developed by Franklin Associates, Ltd. (FAL) as part of the original effort or subsequent updates.

Most of the materials included in this analysis are assumed to undergo closed-loop recycling (i.e., materials are remanufactured into a similar product). However, mixed paper is recycled in an open loop into boxboard and paper towels.[3] Thus, the exhibits in this chapter show data not only for the 15 materials of interest, but also for boxboard and paper towels. Because recycling processes data are similar for HDPE, LDPE, and PET, we adopted the approach used by ORD of using a single energy profile (fuel mix and energy intensity) for all recycled plastics. For steel cans, we developed GHG estimates for virgin production using the basic oxygen furnace process,[4] and for recycled production, we used the electric arc furnace process.[5]

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[3] FAL provided virgin and recycled manufacturing and transportation data for boxboard and paper towels. For virgin boxboard, only one type of product is manufactured, as shown in Exhibits 2-3 and 2-4. For recycled boxboard, there are two types of products, and we obtained two different sets of manufacturing and transportation data as shown in Exhibits 2-5 and 2-6. We have labeled the two types of boxboard as boxboard "A" and boxboard "B." These two products differ only with respect to their recycled material inputs (i.e., the proportion of newspaper, corrugated cardboard, office paper, and coated paper used to manufacture either boxboard "A" or boxboard "B"); both products share the same manufacturing and transportation values for virgin inputs.

[4] Note that the basic oxygen furnace process can utilize approximately 25 percent recycled inputs.

[5] Note that when recovered steel cans are used as inputs to an electric arc furnace, the resulting steel is not suited for milling to the thinness of steel sheet needed for use in making new steel cans. Thus, a more precise approach would have been to model recovery of steel cans as an open-loop process, in which recovered steel cans

We used carbon coefficients from the U.S. Department of Energy's Energy Information Administration for all fuels except electricity.[6] The carbon coefficient for electricity was based on the weighted average carbon coefficients for all fuels used to generate electricity in the United States.[7]

Because the carbon coefficients from these sources accounted for only the CO_2 emissions from combustion of each type of fuel, we added to these carbon coefficients (1) the average amount of CH_4 emitted during the production, processing, and transportation of fossil fuels, and (2) the average CO_2 emissions from oil production, due to the flaring of natural gas. We calculated the average fugitive GHG emissions associated with U.S. production of coal, oil, and natural gas. The resulting average estimates for fugitive GHG emissions from fossil fuel production were 0.92 kilograms of carbon equivalent per million Btu (kg CE/million Btu) for coal, 0.10 kg CE/million Btu for oil, and 0.70 kg CE/million Btu for natural gas.[8]

The carbon coefficients that reflect both CO_2 and CH_4 emissions are supplied in Exhibit 2-1. (All exhibits are provided at the end of this chapter.)

The process and transportation GHG values are shown in summary form in Exhibit 2-2. For each product and each type of input (virgin or recycled), we summed the estimates for process and transportation GHG emissions, as shown in columns "b" (for virgin inputs) and "c" (for recycled inputs) of Exhibit 2-2. We also estimated the energy-related GHG emissions from manufacturing each material from the current mix of virgin and recycled inputs. These values are shown in column "e." (The remaining two columns of Exhibit 2-2 are discussed later in this chapter.)

The energy intensity and fuel mix data are provided in Exhibits 2-3 through 2-6. For most materials, the data in the exhibits are for manufacturing processes that either use (1) 100 percent virgin inputs or (2) 100 percent recycled inputs.[9]

To estimate the types and amounts of fuels used for process and transportation energy, ORD and FAL relied on published data (such as engineering handbooks and published production data), contacts with industry experts, and review by stakeholders and trade organizations. ORD and FAL counted all energy, no matter where it was used. For example, much aluminum produced in the United States is made

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are made into some other steel product. By modeling recovery of steel cans as a closed-loop process, we implicitly assumed that 1 ton of steel produced from recovered steel cans in an electric arc furnace displaces 1 ton of steel produced from virgin inputs in a basic oxygen furnace. We believe this is a reasonable assumption. (For the fabrication energy required to make steel cans from steel, we used the values for fabrication of steel cans from steel produced in a basic oxygen furnace.)

[6] U.S. Department of Energy, Energy Information Administration. 2000. *Annual Energy Review: 1999.*

[7] FAL reported the Btu value for electricity in terms of the Btu of fuel combusted to generate the electricity used at the factory, rather than the (much lower) Btu value of the electricity that is delivered to the manufacturer. Thus, FAL had already accounted for the efficiency of converting fuels to electricity, and the losses in transmission and distribution of electricity. We therefore did not need to account for these factors in the carbon coefficient for electricity.

[8] ICF Consulting. 1995. Memorandum, "Fugitive Methane Emissions from Production of Coal, Natural Gas, and Oil," August 8, updated to use global warming potential for CH_4 of 21.

[9] In the FAL data set, the one exception is the data for steel cans made from virgin inputs, for which FAL provided data for manufacture from 80 percent virgin inputs and 20 percent recycled inputs. We extrapolated from this data (and the corresponding values for production using 100 percent recycled inputs) to obtain estimates of the energy inputs for manufacturing these materials from 100 percent virgin inputs. Similarly, for corrugated cardboard, ORD assumed that a virgin corrugated box contains a minimum of 14.7 percent total recycled content.

from bauxite that is mined and processed into alumina in other countries. The energy required for overseas bauxite mining and processing is counted in the analysis.

Neither the ORD nor the FAL transportation data reflect transportation of the finished manufactured product to the retailer and consumer. This omission is only important in estimating the GHG reductions associated with source reduction (i.e., source reduction reduces transportation energy). It is not relevant in analyzing GHG implications of recycling compared to other post-consumer management options, because the amount of transportation energy from the factory to the consumer is about the same whether the product is manufactured from virgin inputs or recycled inputs. Even for the source reduction analysis, we expect that the transportation energy from factory to consumer would represent a very small fraction of the total process and transportation energy.

Finally, it should be noted that during our extensive review of ORD and FAL data, we examined the most critical assumptions and data elements that each model used to ensure that they accurately reflect the energy requirements of the raw materials acquisition and manufacturing for the material types considered. Nevertheless, we recognize that different manufacturers making the same product use somewhat different processes with different energy requirements and fuel mixes, and that there are limited data on the extent to which various processes are used. Thus, although our goal was to estimate as accurately as possible the national average GHG emissions for the manufacture of each material from virgin and recycled inputs, it is quite likely that individual companies will have GHG emissions that vary significantly from those estimated here.

2.2 NON-ENERGY GHG EMISSIONS FROM MANUFACTURING AND RAW MATERIALS ACQUISITION

In addition to GHG emissions from energy use, we also accounted for three additional sources of GHGs in manufacturing processes:

- When limestone (calcium carbonate, or $CaCO_3$) is converted to lime (calcium oxide, or CaO), CO_2 is emitted. Significant quantities of lime are used in the production of steel, aluminum, and, to a much lesser extent, office paper.
- CH_4 emissions from natural gas pipelines and processing of natural gas are associated with the manufacture of plastic products.
- Perfluorocarbons (CF_4 and C_2F_6) are emitted during aluminum smelting.

For plastics and office paper, process non-energy GHG emissions are associated only with production using virgin inputs. In the case of steel, however, these emissions result when either virgin or recycled inputs are used (because lime is used in the production of steel from recycled as well as virgin inputs).

The process non-energy GHGs for each material are shown in the second-to-last column of Exhibits 2-3 and 2-5 (for manufacture from virgin inputs and recycled inputs, respectively), and are repeated in column "f" of Exhibit 2-2. ORD supplied the non-energy CO_2 emissions for aluminum, glass, corrugated cardboard, and newspaper. We based our calculation for PFC emissions from aluminum on the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998*.[10]

[10] To estimate aluminum PFC emissions on a per-ton basis, we divided the inventory estimates for CF_4 and C_2F_6 emissions from aluminum by total primary aluminum production, yielding units in MTCE/ton.

Non-energy CO_2 emissions for the other materials, as well as CH_4 emissions, are based on the original analysis supporting the first edition of this report.[11]

2.3 RESULTS

Our estimates of the total GHG emissions from raw materials acquisition and manufacturing for each material are shown in Exhibit 2-2, column "g." In order to obtain these estimates, we summed the energy-related GHG emissions (column "e") and the non-energy GHG emissions (column "f").

The process energy and transportation GHG values that were developed as described earlier in this chapter are shown in the third-to-last columns of Exhibits 2-3 and 2-5, and in the last columns of Exhibits 2-4 and 2-6 (the last columns of Exhibits 2-3 and 2-5 show the total process energy GHG emissions).

Total GHG emissions associated with the raw materials acquisition and manufacturing stage of the product life cycle are shown in the three righthand columns of Exhibit 2-2. These three columns correspond to the type of inputs that occur during the recycling process: virgin inputs, recycled inputs, or the current mix of virgin and recycled inputs.

2.4 LIMITATIONS

There are several limitations to the analysis of the GHG emissions associated with raw materials acquisition and manufacturing, as described below.

The approach used in this analysis provides values for the average GHG emission rates per ton of material produced, not the marginal emission rates per incremental ton produced. In some cases, the marginal emission rates may be significantly different. For example, reducing production of plastic products from virgin inputs may not result in a proportional decrease in CH_4 emissions from natural gas pipelines and natural gas processing. The operating pressure in natural gas pipelines and the number and size of leaks in the pipeline determine CH_4 emissions from natural gas pipelines. Consequently, the amount of natural gas consumed at one end of the pipeline (e.g., to make plastic) does not affect the level of pipeline CH_4 emissions in a direct, linear way. As another example, long-term reductions in electricity demand could selectively reduce demand for specific fuels, rather than reducing demand for all fuels in proportion to their representation in the current average fuel mix. This analysis estimates average carbon conversion rates largely because the marginal rates are much more difficult to estimate. Nevertheless, we believe the average values provide a reasonable approximation of the GHG emissions.

In addition, the analysis assumes that the GHG emissions from manufacturing a given product change in a linear fashion as the percentage of recycled inputs moves from 0 to 100 percent. In other words, the analysis assumes that both the energy intensity and the fuel mix change in linear paths over this range. However, it could be that GHG emissions from manufacturing move in a non-linear path, (e.g., some form of step function) when the percentage of recycled inputs changes, due to capacity limits in manufacturing or due to the economics of manufacturing processes.

The transportation energy required for the final stage of transportation (to the consumer) was not considered. Consequently, some carbon emissions reductions for "lightweighted" products for these transportation stages were not considered; these savings are likely to be small.

The information used in this analysis represents the best available data from published and unpublished industry sources, some of it quite dated. Therefore, the data may not necessarily reflect recent trends in industrial energy efficiency or changes in the fuel mix.

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[11] ICF Consulting. 1994. Memorandum, "Detailed Analysis of Greenhouse Gas Emissions Reductions from Increased Recycling and Source Reduction of Municipal Solid Waste," July 29, p. 48 of the Appendix prepared by Franklin Associates, Ltd., dated July 14, 1994.

Finally, this static analysis does not consider potential future changes in energy usage per unit of output or alternative energy (e.g., non-fossil) sources. Reductions in energy inputs due to efficiency improvements could occur in either virgin input processes or recycled input processes. Efficiency improvements and switching to alternative energy sources will result directly in GHG emissions reductions and may change the reductions possible through increased recycling or source reduction.

Exhibit 2-1 Carbon Coefficients For Selected Fuels					
Fuel Type	**Metric Tons of CO_2 from Combustion Per Million Btu**	**kg Carbon Equivalent (CE) from Combustion Per Million Btu**	**Metric Tons of Fugitive CH_4 Emissions Per Million Btu**	**kg CE from Fugitive Methane Emissions Per Million Btu**	**kg CE Emitted Per Million Btu Consumed**
Gasoline	0.07	19.25	0.00002	0.098	19.35
LPG	0.06	16.91	0.00002	0.10	17.01
Distillate Fuel	0.07	19.87	0.00002	0.10	19.97
Residual Fuel	0.08	21.41	0.00002	0.10	21.51
Diesel	0.07	19.87	0.00002	0.10	19.97
Oil/Lubricants	0.07	20.16	0.00002	0.10	20.26
Steam (non-paper products)	0.07	18.21	0.00011	0.61	18.81
Steam (paper products)	0.05	12.92	0.00004	0.25	13.17
National Average Fuel Mix for Electricity	0.06	15.79	0.00010	0.59	16.25
National Average Fossil Fuel Mix for Electricity	0.08	23.18	0.00015	0.86	24.04
Coal Used for Electricity	0.09	24.86	0.00016	0.92	25.78
Coal Used by Industry (Non-Coking Coal)	0.09	25.10	0.00016	0.92	26.02
Natural Gas	0.05	13.78	0.00012	0.70	14.48
Nuclear	0.00	0.84			0.84
Other (Petroleum Coke)	0.10	27.78	0.00002	0.10	27.87

Exhibit 2-2
GHG Emissions from the Manufacture of Selected Materials
(Metric Tons of Carbon Equivalent (MTCE) per Ton of Product)

(a)	(b)	(c)	(d)	(e)	(f)			(g)		
	Virgin Input Combined Process and Transportation Energy Emissions	Recycled Input Combined Process and Transportation Energy Emissions		Current Mix Combined Process and Transportation Energy Emissions	Process Non-Energy Emissions (MTCE per Ton of Product)			Average Combined Process and Transportation Energy and Process Non-Energy Emissions (MTCE per Ton of Product)		
Type of Product	(MTCE per Ton of Product Made With Virgin Inputs)	(MTCE per Ton of Product Made With Virgin Inputs)	Percent Recycled Inputs in the Current Mix of Virgin and Recycled Inputs	(MTCE per Ton of Product Made With the Current Mix of Virgin and Recycled Inputs)	Virgin Inputs	Recycled Inputs	Current Mix	Virgin Inputs	Recycled Inputs	Current Mix
Aluminum Cans	3.52	0.25	49%	1.90	1.15	0.02	0.59	4.67	0.27	2.49
Steel Cans	0.77	0.27	44%	0.55	0.24	0.24	0.24	1.01	0.51	0.79
Glass Containers	0.11	0.07	23%	0.10	0.04	0.00	0.03	0.16	0.07	0.14
HDPE	0.48	0.04	9%	0.44	0.05	0.00	0.05	0.53	0.04	0.49
LDPE	0.59	0.04	4%	0.56	0.05	0.00	0.05	0.64	0.04	0.61
PET	0.55	0.04	18%	0.46	0.03	0.00	0.02	0.58	0.04	0.49
Corrugated Boxes	0.22	0.25	62%	0.24	0.00	0.00	0.00	0.22	0.25	0.24
Magazines/Third-class Mail	0.46	0.46	22%	0.46	0.00	0.00	0.00	0.46	0.46	0.46
Newspaper	0.59	0.34	52%	0.46	0.00	0.00	0.00	0.59	0.34	0.46
Office Paper	0.27	0.37	32%	0.30	0.01	0.00	0.00	0.28	0.37	0.31
Phonebooks	0.67	0.41	12%	0.64	0.00	0.00	0.00	0.67	0.41	0.64
Textbooks	0.59	0.57	13%	0.59	0.00	0.00	0.00	0.59	0.57	0.59
Dimensional Lumber	0.05	0.07	0%	0.05	0.00	0.00	0.00	0.05	0.07	0.05
Medium-density Fiberboard	0.10	0.12	0%	0.10	0.00	0.00	0.00	0.10	0.12	0.10
Mixed Paper										
Broad Def'n (= Boxboard "A")	0.32	0.43	51%	0.38	0.00	0.00	0.00	0.32	0.43	0.38
Residential Def'n (= Boxboard "B")	0.32	0.43	53%	0.38	0.00	0.00	0.00	0.32	0.43	0.38
Office Def'n (= Paper Towels)	0.91	0.75	38%	0.85	0.00	0.00	0.00	0.91	0.75	0.85

Explanatory notes: To estimate the GHG emissions from manufacturing, we first estimated the process and transportation GHG emissions when 100 percent virgin inputs, or 100 percent recycled inputs, are used. For each product and each type of input (virgin or recycled), we summed the estimates for process and transportation GHG emissions. Next we estimated the GHG emissions from manufacturing each material from the current mix of virgin and recycled inputs. We began with estimates of the percentage of recycled inputs currently used in the manufacture of each material, as shown in column "d." We used these percentages to develop a weighted average value for the GHG emissions associated with the manufacture of each material from the current mix of virgin and recycled inputs. Specifically, we used the estimate of the percentage of recycled inputs in the current mix, together with the estimates for GHG emissions from manufacture using virgin or recycled inputs, to develop estimates of GHG emissions from manufacture using the current mix of virgin and recycled inputs (column "e").

Explanatory notes for Exhibit 2-2 (continued):

Column "f" shows estimates of the process non-energy GHG emissions from manufacturing. First, this column shows the process non-energy GHG emissions when virgin inputs are used. Then it shows the emissions when recycled inputs are used (these values are simply copied from the final columns of Exhibits 2-3 and 2-5). Finally, column "f" shows the process non-energy GHG emissions from manufacturing each product from the current mix of virgin and recycled inputs. The values for the current mix are the weighted averages of the values for virgin and recycled inputs, based on the percentage of recycled inputs used in the current mix (as shown in column "d").

The total GHG emissions from manufacturing are shown in column "g." This column shows total GHG emissions when a product is manufactured from virgin or recycled inputs, or from the current mix of virgin and recycled inputs.

Exhibit 2-3

GHG Emissions Per Ton of Product Manufactured from Virgin Inputs

Process GHGs Only

Type of Product	Process Energy (Million Btu Per Ton of Product)	Average Fuel Mix (in Percent): Gasoline	LPG	Distillate Fuel	Residual Fuel	Biomass/Hydro	Diesel	Electricity	Coal	Natural Gas	Nuclear	Other	Total	Process Energy GHG Emissions (MTCE/Ton of Product)	Process Non-Energy GHG Emissions (MTCE/Ton of Product)	Total Process GHG Emissions (MTCE/Ton of Product)
Aluminum Cans	205.80	0.16	0.01	0.82	4.06	0.03	0.50	80.36	0.83	13.04	0.17	0.02	100	3.36	1.15	4.51
Steel Cans	31.58	0.21	0.00	5.06	0.35	0.00	0.00	21.02	53.90	19.45	0.00	0.00	100	0.68	0.24	0.91
Glass	6.49	0.55	0.00	1.45	0.47	0.03	0.00	10.12	7.18	79.95	0.23	0.02	100	0.10	0.04	0.15
HDPE	28.69	0.00	0.00	0.00	33.14	1.16	0.00	5.64	4.59	51.35	4.00	0.13	100	0.48	0.05	0.53
LDPE	35.26	0.00	0.00	0.00	32.59	1.56	0.00	7.66	6.15	46.52	5.36	0.17	100	0.59	0.05	0.64
PET	32.82	0.00	0.00	0.00	36.67	1.62	0.00	7.10	6.42	42.41	5.59	0.18	100	0.55	0.03	0.58
Corrugated Cardboard	25.13	0.01	0.00	0.02	0.54	61.33	1.20	14.06	15.52	7.31	0.01	0.00	100	0.19	0.00	0.20
Magazines/Third-class Mail	32.99	0.15	0.01	0.32	8.30	24.27	0.00	25.40	17.11	24.33	0.11	0.01	100	0.46	0.00	0.46
Newspaper	39.92	0.25	0.00	0.52	0.75	9.09	0.68	54.21	1.75	32.43	0.27	0.04	100	0.58	0.00	0.58
Office Paper	37.01	0.08	0.00	0.17	4.33	60.53	0.00	13.24	8.92	12.68	0.06	0.01	100	0.27	0.01	0.28
Phonebooks	39.61	0.18	0.01	0.38	9.99	8.86	0.00	30.56	20.59	29.28	0.13	0.02	100	0.67	0.00	0.67
Textbooks	35.07	0.18	0.01	0.38	9.96	9.14	0.00	30.47	20.52	29.19	0.13	0.02	100	0.59	0.00	0.59
Dimensional Lumber	2.53	1.57	0.00	0.00	0.00	32.81	15.99	43.09	0.00	6.53	0.00	0.00	100	0.03	0.00	0.03
Medium-density Fiberboard	10.18	0.14	0.00	0.38	0.05	51.90	1.26	27.61	0.00	18.68	0.00	0.00	100	0.08	0.00	0.08
Boxboard	32.26	0.00	0.00	0.00	0.94	59.34	1.36	5.32	24.01	9.02	0.00	0.00	100	0.29	0.00	0.29
Paper Towels	73.44	0.00	0.00	0.01	1.80	24.89	0.45	28.15	2.93	41.78	0.00	0.00	100	0.87	0.00	0.87

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

Exhibit 2-4

GHG Emissions Per Ton of Product Manufactured from Virgin Inputs

Transportation GHGs Only

Type of Product	Transportation Energy (Million Btu Per Ton of Product)	Average Fuel Mix (in Percent)												Transportation Energy GHG Emissions (MTCE/Ton of Product)
		Gasoline	LPG	Distillate Fuel	Residual Oil	Biomass/Hydro	Diesel	Electricity	Coal	Natural Gas	Nuclear	Other	Total	
Aluminum Cans	7.47	0.10	0.08	0.39	79.88	0.05	11.34	0.34	0.86	6.58	0.33	0.05	100	0.16
Steel Cans	4.60	0.00	0.00	0.00	1.76	0.00	98.24	0.00	0.00	0.00	0.00	0.00	100	0.09
Glass	0.58	0.10	0.08	0.40	2.64	0.04	88.95	0.00	0.89	6.51	0.36	0.03	100	0.01
HDPE	NA													NA
LDPE	NA													NA
PET	NA													NA
Corrugated Cardboard	1.31	0.05	0.00	0.05	0.27	0.01	98.51	0.00	0.00	1.07	0.04	0.01	100	0.03
Magazines/Third-class Mail	NA													NA
Newspaper	0.50	0.10	0.08	0.39	3.63	0.05	87.97	0.00	0.86	6.53	0.34	0.05	100	0.01
Office Paper	NA													NA
Phonebooks	NA													NA
Textbooks	NA													NA
Dimensional Lumber	0.88	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	100	0.02
Medium-density Fiberboard	1.01	0.00	0.00	0.00	0.06	0.00	98.10	0.00	0.00	1.84	0.00	0.00	100	0.02
Boxboard	1.79	0.00	0.00	0.00	0.05	0.00	99.93	0.00	0.00	0.01	0.00	0.00	100	0.04
Paper Towels	2.07	0.00	0.00	0.00	0.52	0.00	99.46	0.01	0.00	0.02	0.00	0.00	100	0.04

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

Note that for some materials, transportation data was included in the process energy estimates and not provided separately, denoted by "NA" in this table.

Exhibit 2-5
GHG Emissions Per Ton of Product Manufactured from Recycled Inputs
Process GHGs Only

Type of Product	Process Energy (Million Btu Per Ton of Product)	Average Fuel Mix (in Percent): Gasoline	LPG	Distillate Fuel	Residual Fuel	Biomass/Hydro	Diesel	Electricity	Coal	Natural Gas	Nuclear	Other	Total	Process Energy GHG Emissions (MTCE/Ton of Product)	Process Non-Energy GHG Emissions (MTCE/Ton of Product)	Total Process GHG Emissions (MTCE/Ton of Product)
Aluminum Cans	14.85	0.27	0.01	5.12	0.44	0.05	0.52	63.74	0.75	28.78	0.29	0.04	100	0.24	0.02	0.26
Steel Cans	11.78	0.01	0.17	0.07	0.03	0.00	0.00	77.28	0.65	21.80	0.00	0.00	100	0.19	0.24	0.43
Glass	4.32	0.55	0.00	0.39	0.26	0.03	0.00	5.10	0.54	92.91	0.21	0.02	100	0.06	0.00	0.06
HDPE	4.17	0.03	0.03	1.05	1.24	12.48	0.05	33.21	0.02	20.34	0.09	31.44	100	0.04	0.00	0.04
LDPE	4.17	0.03	0.03	1.05	1.24	12.48	0.05	33.21	0.02	20.34	0.09	31.44	100	0.04	0.00	0.04
PET	4.17	0.03	0.03	1.05	1.24	12.48	0.05	33.21	0.02	20.34	0.09	31.44	100	0.04	0.00	0.04
Corrugated Cardboard	11.73	0.01	0.05	0.05	0.66	0.00	0.31	51.11	38.40	9.40	0.01	0.00	100	0.23	0.00	0.23
Magazines/Third-class Mail	31.97	0.16	0.01	0.32	8.45	22.85	0.00	25.87	17.43	24.79	0.11	0.01	100	0.46	0.00	0.46
Newspaper	21.98	0.30	0.00	0.58	0.30	0.05	0.00	57.75	1.09	39.59	0.30	0.04	100	0.34	0.00	0.34
Office Paper	20.12	0.20	0.01	0.42	10.96	0.02	0.00	33.53	22.58	32.12	0.14	0.02	100	0.37	0.00	0.37
Phonebooks	22.02	0.20	0.01	0.42	10.96	0.02	0.00	33.53	22.58	32.12	0.14	0.02	100	0.41	0.00	0.41
Textbooks	33.51	0.21	0.01	0.60	10.02	8.38	0.00	30.40	20.61	29.57	0.17	0.02	100	0.57	0.00	0.57
Dimensional Lumber	3.17	0.00	0.00	0.00	0.00	0.00	23.61	76.39	0.00	0.00	0.00	0.00	100	0.05	0.00	0.05
Medium-density Fiberboard Made from Reused Dimensional Lumber	10.99	0.13	0.00	0.35	0.04	48.05	8.56	25.56	0.00	17.29	0.00	0.00	100	0.09	0.00	0.09
Boxboard Made from Broad Definition of Mixed Paper	22.53	0.00	0.03	0.02	0.36	0.00	0.49	67.46	24.36	7.25	0.00	0.00	100	0.42	0.00	0.42
Boxboard Made from Residential Definition of Mixed Paper	22.53	0.00	0.03	0.02	0.36	0.00	0.49	67.46	24.36	7.25	0.00	0.00	100	0.42	0.00	0.42
Paper Towels Made from Recoverd File Stock	51.69	0.00	0.00	0.00	0.45	6.94	0.15	36.32	0.98	55.14	0.00	0.00	100	0.74	0.00	0.74

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

* Recycled boxboard using a "broad" definition of mixed paper comprised of 24 percent newsprint, 48 percent corrugated cardboard, 20 percent office paper, and 8 percent coated paper.

** Recycled boxboard using a "residential" definition of mixed paper comprised of 23 percent newsprint, 53 percent corrugated cardboard, 14 percent office paper, and 10 percent coated paper.

*** Recycled boxboard using an "office paper" definition of mixed paper comprised of 21 percent newsprint, 5 percent corrugated cardboard, 38 percent office paper, and 36 percent coated paper.

Exhibit 2-6
GHG Emissions Per Ton of Product Manufactured from Recycled Inputs
Transportation GHGs Only

Type of Product	Transportation Energy (Million Btu Per Ton of Product)	Average Fuel Mix (in Percent)												Transportation Energy GHG Emissions (MTCE/Ton of Product)
		Gasoline	LPG	Distillate Fuel	Residual Oil	Biomass/Hydro	Diesel	Electricity	Coal	Natural Gas	Nuclear	Other	Total	
Aluminum Cans	0.40	0.08	0.06	0.32	3.07	0.04	90.11	0.00	0.68	5.32	0.27	0.04	100	0.01
Steel Cans	4.03	0.00	0.00	0.00	0.01	0.00	99.99	0.00	0.00	0.00	0.00	0.00	100	0.08
Glass	0.34	0.10	0.08	0.41	2.59	0.04	89.01	0.00	0.89	6.51	0.35	0.03	100	0.01
HDPE	0.08	0.00	0.00	0.00	56.50	0.00	5.96	2.53	0.00	35.01	0.00	0.00	100	0.00
LDPE	0.08	0.00	0.00	0.00	56.50	0.00	5.96	2.53	0.00	35.01	0.00	0.00	100	0.00
PET	0.08	0.00	0.00	0.00	56.50	0.00	5.96	2.53	0.00	35.01	0.00	0.00	100	0.00
Corrugated Cardboard	0.80	0.05	0.00	0.05	0.22	0.01	98.55	0.00	0.00	1.07	0.04	0.00	100	0.02
Magazines/Third-class Mail	NA													0.00
Newspaper	0.03	0.10	0.08	0.39	3.75	0.05	87.87	0.00	0.86	6.53	0.32	0.05	100	0.00
Office Paper	NA													0.00
Phonebooks	NA													0.00
Textbooks	NA													0.00
Recycled Lumber from	0.97	0.00	0.00	0.00	0.00	0.00	100.06	0.00	0.00	0.00	0.00	0.00	100	0.02
Medium-density Fiberboard Made from Reused Dimensional Lumber	1.27	0.00	0.00	0.00	0.05	0.00	98.46	0.00	0.00	1.47	0.00	0.00	100	0.03
Boxboard Using the "Broad Definition" for Mixed Paper	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
Boxboard Using the "Single-Family Residential Definition" for Mixed Paper	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
Paper Towels Using "Office Paper" for Mixed Paper	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

Note that for some materials, transportation data was included in the process energy estimates and not provided separately, denoted by "NA" in this table.

* Recycled boxboard using a "broad" definition of mixed paper comprised of 24 percent newsprint, 48 percent corrugated cardboard, 20 percent office paper, and 8 percent coated paper.

** Recycled boxboard using a "residential" definition of mixed paper comprised of 23 percent newsprint, 53 percent corrugated cardboard, 14 percent office paper, and 10 percent coated paper.

*** Recycled boxboard using an "office paper" definition of mixed paper comprised of 21 percent newsprint, 5 percent corrugated cardboard, 38 percent office paper, and 36 percent coated paper.

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